CONSTRUCTION PRODUCTIVITY AND COST REPORTING

By

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ABSTRACT

This research report improves the likelihood of meeting construction project and business objectives by implementing self-perform labor productivity and cost reporting process. The overall approach includes a literature review of construction productivity reporting, evaluating existing reporting processes of an operating construction company, evaluating reporting process improvements on a model project, interviewing subject matter experts in cost control, and evaluating model project survey responses. The research approach involves evaluating a construction organization's existing processes for estimating in standard units of measure, reviewing existing procedures for establishing cost control budgets, researching methods for developing a process for tracking installed material quantities, researching methods for preparing weekly productivity reports, and labor unit rate benchmarking. Additionally, this report includes examining methods for reducing operational rework for projects executed in the construction industry by implementing a proactive corrective action based on verified actual cost and productivity rates. The results of this research demonstrate that utilizing project management methodology as an approach to researching construction cost and productivity reports improves the success of implementing company standardized reporting processes and provides an opportunity to meet business objectives.

KEYWORDS

- Construction Productivity Reporting
- Labor Unit Rate
- Measuring Labor Productivity
- Construction Cost Estimate
- Productivity Variance
- Construction Cost Reporting

CONSTRUCTION PRODUCTIVITY AND COST REPORTING

INTRODUCTION

PROBLEM STATEMENT

The construction industry has consistently reported that labor productivity is the most significant concern for project cost controls. For construction companies to increase profit margins, it is essential that cost control processes for self-perform labor are implemented. Although labor productivity is a known risk for the majority of the construction industry, many organizations lack a formal cost reporting process that enables project teams to reduce the threats and optimize the opportunities presented by labor productivity management. It is characteristic for construction organizations to have formal accounting procedures at the macro level which provide an overall health check of organization productivity at the parent company level; however, there is less emphasis on improving the micro level of productivity management where installed material quantities are physically counted. Furthermore, if project teams lack the opportunity to respond timely to labor productivity concerns, it is highly likely that cost overruns are unrecoverable. Thus, the need for implementing a labor productivity reporting process is a critical prerequisite for achieving project cost control success.

INTRODUCTION

This report aims to provide research and practice-based recommendations for applying a labor productivity cost reporting process within an operating construction organization. White paper analysis is the primary source of information compiled regarding labor productivity reporting. A construction organization volunteered to allow the researcher to evaluate, organize, monitor and control the labor productivity reporting processes within ongoing projects. Each project that participates in the productivity reporting process is a prototype, and the results of each prototype will provide an iterative approach to validating labor reporting improvements. The data compiled from each prototype model project is used to evaluate the process and provide opportunities for the project team to make improvements to the cost reporting procedures in real-time. The project team stakeholders' experiences and opinions are compiled within an anonymous user survey. Lastly, the construction organization cost control subject matter experts were interviewed to provide insights for implementing organizational process improvements. The survey and interview data offer a perspective for the level of project management maturity and willingness of performing labor cost reporting. Several cost control management tools are developed included daily report template, timecard template, installed quantity tracking tool, and cost reports. The

completion of the research consists of a recommendation to the construction organization for further the cost control improvement process and for improving the Construction Extension to the PMBOK Guide.

ORGANIZATIONAL STRUCTURE AND BUSINESS CASE

The construction organization that volunteered to partake in the productivity and cost reporting improvement process is based in Alaska. The company structure includes several subsidiary companies which specialize in both vertical and horizontal construction. The company has completed projects in a wide range of industries including heavy civil, industrial, modular, healthcare, military, education, tourism, transportation, power generation, and pre-engineered metal structures, among others. The geographic reach of the company is expansive with projects completed in the continental United States, Asia, US Pacific Islands, and in nearly all remote areas of Alaska including the north slope of Alaska in the state's most northern village community of Utqiagvik (previously known as Barrow), to the Alaska Aleutian Islands on Shemya Island. The organizational management requested the company name and employee information remain anonymous.

Although the company has successfully executed numerous projects, there has been a minimal effort to implement project level cost controls for self-perform labor productivity. Thus, the success of labor performance varies when evaluating project performance. The existing cost control procedures are ad-hoc with common language and processes, and limited standardized systems across subsidiaries. Strict financial accounting procedures are used by the accounting, and upper management staff, including standards and procedures, provided by the Generally Accepted Accounting Principles, also referred to as GAAP; however, less emphasis on the project level control procedures. Current processes require project teams to submit monthly cost reports, which included an estimate to complete value and forecasted cost values for each cost account. The values of the monthly cost reports for each project are compiled at each subsidiary level work-in-progress report, also called WIP report, and a final company-level performance dashboard is distributed to executives and board members. This process has proven useful for communicating financial health of the organization and potential year-end profit; however, this process does not provide the project team an effective avenue to identify leading or lagging cost performance indicators. Thus, the ability to implement a timely corrective action is squandered. For this reason, the company is exploring project level labor productivity reporting to improve profit margins by optimizing labor cost productivity.

LITERATURE REVIEW

RESEARCH APPROACH

The literature review research approach focused on sources that included defining labor productivity and the process by which construction projects obtain, organize and communicate data. Keyword search for construction productivity provided a plethora of results including textbooks, white papers, scholarly review, business articles, and published research. The literature was selected based on information that supports establishing a basis for controlling project labor cost. The following topics were explored: defining labor productivity; the use of the project estimate to establish a control budget with cost accounts and communicating labor cost productivity in tabular and graphical reports.

DEFINITION OF PRODUCTIVITY

Productivity measures the efficiency of production. It expresses the fundamental relationship that exists between what is used to produce the product (inputs) and how much product is produced (output) (Park, 2006). The productivity equation is:

Productivity = Input / Output

Construction companies are interested in the rate that craft workers are installing materials compare to the estimated rate, to do this a labor productivity rate calculation is applied. Labor productivity considers only labor as an input is commonly used in the construction industry (Park, 1999). The labor productivity equation is:

Labor Productivity = Input / Output = Actual Work Hours / Installed Quantity

As shown in the above equation, labor productivity is calculated in actual work hours per installed quantity; that is, the number of actual work hours required to perform the appropriate units of work. Therefore, when defined in this manner the lower the productivity measurement value, the better the productivity performance (Park, 2006). Merely the number of work hours used for the number of units installed, for example, twenty labor hours were used to install 100 linear feet of culvert pipe equates to a labor productivity rate of 0.2 MH/LF (labor hours per linear foot).

Labor Productivity = Actual Work Hours / Installed Quantity = 20 MH / 100 LF = 0.2 MH/LF

Labor productivity rates are expressed in terms of the number of units per labor hours worked and is generally used for field productivity reporting and estimating. The unit of output varies according to the circumstance (Rojas, 2008). Common construction units of measure are square feet (SF), cubic yard (CY), linear foot (LF), each (EA), board-foot (BF). Each unit of measure is reported in corresponding

productivity units based on the actual hours required to install the given quantity of material. Examples include the number of bricks laid per hours, cubic yards of concrete poured per hours and square feet of flooring installed per hour.

Labor productivity rates are also expressed in time or money as a basis of measurement. By replacing the number of labor hours by the cost of the labor hour, or entire crew per hour the rate is expressed as a dollar per unit. For example, $50 per 20 labor hours was used to install 100 linear feet (LF) of culvert pipe equate to a labor cost productivity rate of $10 per linear foot.

Labor Productivity Cost = (Cost per Hour x Actual Work Hours) / Installed Quantity =

($50 X 20 MH) / 100 LF = $10 per LF

Also, labor productivity cost is expressed in cost per hours when using the total actual labor cost of the operation and the total actual hours. For example, it took 100 hours to complete the culvert installation, and the total labor crew cost was $5000; therefore, the labor productivity cost is $50 per labor hour.

Labor Productivity Cost = Total Crew Labor Cost / Total Labor Hours =

$5000 / 100 MH = $50 per MH

However, measuring money is not as useful as measuring time because the amount of money expended per unit of output varies with some different factors (Rounds et al., 2011). Because labor costs are calculated by varying scales of labor rates based on local laws, unions and contract agreements, labor cost is a less reliable comparison of historical cost. Therefore, labor productivity rate analysis at the project level provides enhanced opportunity for comparison of labor performance.

ESTIMATING

A construction project total budgeted cost is established by the process of completing an estimate of the total effort and total cost required to complete the scope of work. Construction organizations refer to this as the cost estimate. “Although the process of estimating may vary between companies and industries the objective is invariably the same: to produce the best possible determination of the contractor’s cost of performing a construction project as the project is defined and described in the contract documents” (Rounds et al., 2011).

It is common that a contractor will have six components of a detailed cost estimate which include: materials, labor, equipment, subcontractor quotes, indirect costs, and markup. The research is focused on the labor component of the estimate process. As a contractor reviews the documents, one of the first

determination is which scope of work will be constructed by the internal labor forces, also referred to as self-performed work. The organization will choose to self-perform a scope of work that has been completed successfully on past projects. Depending on the organization, a historical labor productivity database may be available to assist with the cost estimate development; or companies will purchase a database of historical productivity rates from a well-known company such as RS Means. “The historical cost database is a tabulation of the contractor’s costs of performing work, by project and by activity, on past projects. This information is generated as each project is performed, and is stored in a systematic manner in the historical cost database. This database is one of the contractor’s most important and most closely-guarded assets (Rounds et al., 2011).” With the scope understood, the cost estimate team will select the corresponding cost codes for each scope of work. The estimated quantity and productivity rate are entered into the estimating software. A standard coding system is highly recommended to assist with organizing the cost estimate. CIS MasterFormat is a coding scheme that is frequently used by general contractors during the cost estimate phase. A sample MasterFormat version 2010 is contained in Appendix A.

Once the self-perform scope is understood, and a corresponding labor productivity rates are determined, the estimator will perform a quantity takeoff of materials that will be installed based on the contract drawings and specifications. The estimator or estimate team must be experienced in analyzing the contract document to determine the correct materials. Each material must be quantified in the unit of measure in which it is installed such as cubic yards of cast-in-place concrete, square yards of carpet, sheets of plywood, bank cubic yards of excavated soil, squares of roofing, and so forth (Rounds et al., 2011). Once the team has compiled a list of materials and quantities with the correct unit of measure into the material takeoff sheet, the historical labor productivity rate can be applied to determine the total labor hours required to complete each scope of work. Exhibit 1 provides an overview of the relationship between the cost estimating process and the project labor controls. The flowchart shows an iterative process from preparing the estimate, monitoring and controlling the work and updating the historical database.

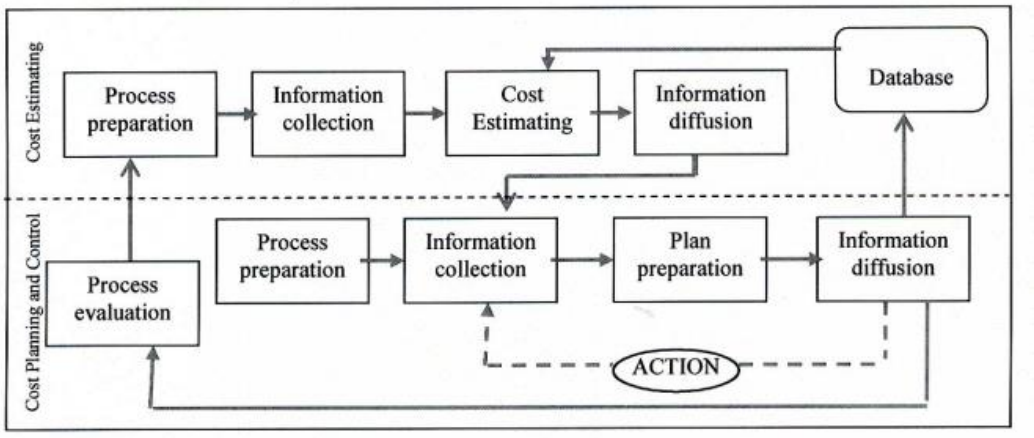

Exhibit 1 - Estimating and Cost Control Flowchart (Kern et al., 2006)

A majority of construction project cost estimates list craft labor as the most significant component of cost; thus, craft labor is correspondingly also the most substantial risk. Therefore, utilizing historical labor productivity rates in conjunction with further analysis of each unique project risk factors including site layout, weather, graphical location, available craft workers, potential management, and many others. After determining the factors that may pose a threat or opportunity to the scope of work that historical unit rate is amended for the specific project cost estimate. The final adjustment of labor productivity rates in the cost estimate reflects the labor hours, productivity rates and labor cost that will be used for the direct labor dollars of the cost proposal or bid, as well as in the project control budget if the project is successfully awarded the project from the requesting client. Additionally, the total labor cost for each cost account must include the value of the direct labor wage per hours and the indirect labor cost of the employee's benefits which include taxes, insurance, workers compensation, vacation pay, fringe benefits, and others.

CONTROL BUDGET

When a contractor is awarded a project, the project team will develop the initial cost breakdown structure (CBS); the cost breakdown structure provides a basic structure for cost control and establishes the Control Budget. "Field construction managers are concerned with cost -what specific operations should and do cost. The structure they will use for this control is the CBS, one level of which will contain the Control Accounts. These are the accounts against which actual costs are collected and compared to those budgeted. They are often at more of a summary level than the crew reporting level. The CBS seldom will have the same structure as that used for cost accounting" (Niel et al., 1990). For construction organizations, the CBS is referred to as the control budget, and cost accounts are called to as phase code in the construction industry. A sample control budget is shown in Exhibit 2.

PROJECT BUDGET							
Cost Code	**Item Name**	**Materials**	**Labor**	**Subcontract**	**Equipment**	**Misc. Budgeted Cost**	**Total**
1000	**GENERAL CONDITIONS**						
1001	BONDS					96770	96770
1002	EXCESS UMBRELLA					26800	26800
1003	BUILDER'S RISK					24900	24900
1004	OWNER PROTECTION LIABILITY					13000	13000
1005	TRAVEL & LODGING					47000	47000
1006	SUBSISTENCE					19000	19000
1007	AGC DUES					23240	23240
1008	PROJECT MANAGER		69500				69500
1009	PROJECT SUPERINTENDENT		115800				115800
1010	FIELD SUPERINTENDENT		62000				62000
1011	FOREMAN		59000				59000
1012	ADMINISTRATIVE ASSISTANT		0				0
1013	TIMEKEEPER		26000				26000
1014	FIELD ENGINEER		7000			10000	17000
1015	JOB CLEANUP— REGULAR		7000			14000	21000
1016	JOB CLEANUP— FINAL		1550			2000	3550
1017	TEMPORARY OFFICE		2200			14000	16200
1018	TEMPORARY OFFICE STORAGE					4800	4800
1019	TEMPORARY TOILETS					5600	5600
1024	TEMPORARY ROADS & DRAINS		1500			3600	5100
1025	TEMPORARY BARRICADES		600			2200	2800
1026	TELEPHONE					5600	5600
1027	TEMPORARY ELECTRICAL					6000	6000
1028	TEMPORARY WATER					2800	2800
1029	TEMPORARY HEAT & AC					1900	1900
1030	OFFICE CONSUMABLES					1800	1800
1031	TEMPORARY FENCING					7400	7400
1032	FIRE EXTINGUISHERS					1100	1100
1033	JOB SIGNS	600				1700	2300
1034	JOB PHOTOS			5000		2500	7500
1035	MOVE IN AND MOVE OUT					22000	22000
1037	CONCRETE TESTING			10000		3900	13900

1061	CONCRETE VIBRATORS				4700		4700
1062	CONCRETE FINISHING MACHINE				5800		5800
1063	AIR COMPRESSOR & PNEUMATIC				4900		4900
1064	WELDING MACHINE & SUPPLIES				5600	1900	7500
1065	TAMPERS				1800		1800
1066	WATER PUMPS				3900		3900
1078	CRANE			60000	38000		98000
1079	CONCRETE BUCKET				26000		26000
1080	FORKLIFT				21500		21500
1081	HAND TOOLS				3450		3450
1082	POWER TOOLS					6200	6200
1091	GAS AND OIL					8100	8100
1092	MAINTENANCE AND REPAIR		1400			28000	29400
9310	HAULING— CRANES			80000	38000		118000
1094	PAYROLL TAXES & INSURANCE					269886	269886
1095	GENERAL CONTRACTOR'S SALES TAX					61098	61098
GENERAL CONDITIONS TOTAL							**$1,401,594**

Exhibit 2 - Sample Project Budget

The CBS and associated cost accounts are populated with the costs from the project estimate. Each cost account's estimated values are the budget baseline, commonly referred to as original estimated value. A sample CBS with phase codes is shown in Exhibit 3. The original estimates are a vital part of the control cost process and serve as cost and productivity targets for the project team. As the project progresses, the baseline budgeted quantities are amended due to a variety of reasons including error and omissions, owner scope additions and change in codes or regulations. As the project becomes further defined, the original estimated values are updated within the control budget. The control budget update is not intended to replace the original estimate, rather establish a corrected control account with the proper values for measuring progress. A proper construction control budget will include values for the original estimate, original budget, and current budget; all of which may be different values. Although not always feasible, a recommended best practice to establish a complete control budget before executing any self-perform labor.

PHASE CODE	DIVISION	COST CODE	DESCRIPTION	ORGINAL BUDGET	UNCOMMITTED COST
3 digit phase must exist in project	**2 digit division must exist in project**	**8 digit cost code must exist in project**	**Budget code description**	**Original budget amount**	**Uncommitted costs amount**
100	01	01111000	General Condition	$1,401,594.00	$1,401,594.00
150	01	01912000	Sub-Guard	$618,548.00	$618,548.00
150	01	01901000	General Liability Insurance	$504,214.00	$504,214.00
150	01	01911000	P&P Bond	$440,576.00	$440,576.00
150	01	01902000	Builders Risk Insurance	$122,382.00	$122,382.00
100	10	10000000	General Trades	$2,242,642.00	$2,242,642.00
200	01	01226000	LEED/BIM Coordination	$75,000.00	$75,000.00
200	01	01222000	Owner Office Equipment	$5,000.00	$5,000.00
200	01	01204000	Owner Office Utilities	$14,000.00	$14,000.00
200	01	01201500	Owner Office Trailer	$21,000.00	$21,000.00
200	01	01590500	Temp Utilities	$939,000.00	$939,000.00
200	02	02300000	Site Work and Paving	$2,325,331.00	$2,325,331.00
200	02	02925000	Landscape and Irrigation	$558,905.00	$558,905.00
200	03	03000000	Key Concrete	$5,560,000.00	$5,560,000.00
200	04	04000000	Masonry	$1,571,430.00	$1,571,430.00
200	05	05100100	Misc. Metals	$2,521,602.00	$2,521,602.00
200	06	06200000	Millwork	$485,568.00	$485,568.00
200	07	07500000	Roofing and Sheet Metal	$1,519,341.00	$1,519,341.00
200	07	07100000	Waterproofing	$364,382.00	$364,382.00
200	08	08000000	Glass and Glazing	$2,592,524.00	$2,592,524.00
200	09	09000000	Drywall	$3,180,799.00	$3,180,799.00
200	09	09300000	Ceramic Tile and Stone	$812,660.00	$812,660.00
200	09	09600000	Flooring	$673,416.00	$673,416.00
200	09	09500000	Painting	$490,421.00	$490,421.00
200	12	12050000	Furnishing	$323,100.00	$323,100.00
200	14	14000000	Elevators	$716,295.00	$716,295.00
200	15	15000000	HVAC/Plumbing	$7,065,008.00	$7,065,008.00
200	15	15050000	Fire Protection	$661,325.00	$661,325.00
200	16	16000000	Electrical	$6,517,765.00	$6,517,765.00
800	23	01902000	Construction Contingency	$1,649,461.00	$1,649,461.00
900	26	01901000	Construction Phase Fee	$1,701,065.00	$1,701,065.00
			Total:	**$47,674,354.00**	**$47,674,354.00**

Exhibit 3 - Sample Project Budget with Phase Codes

MEASURING PROGRESS

Before reporting progress, variances and trends in the labor data are measured. Throughout the life of the project, the project team will track the progress of each self-perform phase code listed in the control budget. As work executed, a field supervisor will verify the quantity of material installed and

record the total labor hours used for each phase code. The process of measuring the installed material quantities varies for the type of construction operation being performed based on the industry, complexity and budgeted effort of the project team. The six regularly used progress measuring techniques are listed below:

Units Complete – Method used for measuring construction operations that are repetitive and involve easily measure units of measure such as Each, Linear Foot and Cubic Yards. The units are physically counted by the number of units complete. This method is an objective approach that is used when the scope of work is fully understood. This method is time-consuming and often expensive. An example of units complete measurement is counting the total number of light poles that are set in a parking lot in a given day (Niel et al., 19870).

Incremental Milestone – Method used for measuring progress for a phase code that is composed of several subtasks and is installed in a sequence of events with each event comprising a percent of the total operation. "The percentage chosen to represent each milestone is normally based on the number of work-hours estimated to be required to that point in relation to the total" (Niel et al., 19870). For example, an operation called Install 4 foot Buried Sewer Pipe involves several steps with the following incremental percentages:

- Transport and Sort Pipe 5%
- Layout and Survey 5%
- Excavation 30%
- Lay and Install Pipe 15%
- Test Pipe 5%
- Backfill and Grade 40%

Start/Finish – Method used for construction operations that are difficult to estimate the total effort or time required. The progress is recorded for short tasks in the range of hours or days as either start with 0 percent or complete with 100 percent. For work that is longer than a week or month, percentages may be added for 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent. This method is not recommended for all types of work as it is difficult to report the percent complete. Examples of this type of progress activity are structural steel rigging, traffic control, cleaning, testing, and monitoring (Niel et al., 19870).

Supervisor Opinion – Method used for progress reported by a subject matter expert, commonly a superintendent or project manager, where a relatively minor operation does not have a unit of measure to

report or other progressing methods are not applicable. The progress is reported as a subjective percent complete based on experience and known risks. Example scope of work for the supervisor opinion methods include administrative support such as safety, mobilization, shipping and receiving, temporary structures, and cleaning. Lastly, caution should be used when implementing a percent complete progress measuring method that is based solely on subjective opinion. Decisions based on information that is not supported by understood data often lead to poor outcomes.

Cost Ratio – Method used for phase codes that include work over a long period and are budged with bulk work hours which may span the life of the project such as project management, project controls, quality assurance, and design submittals (Niel et al., 19870). Progress is reported as a percent complete ratio based on the following equitation:

Percent Complete = Actual cost or Work Hours to Date / Forecast Effort at Completion

Weighted or Equivalent Units – Method used for construction operations that are comprised of several subtasks and span a long period, at least a month long. This method is also referred to as the quantity claiming method. Each subtask unit of measure is different in this method; however, the total amount of work can be claimed as one equivalent weighted unit throughout the progress of the operation. Examples of operations that warrant a quantity claiming plan are mass concrete pours, structural steel erection, heavy civil construction, and industrial pipe installation. The following example is provided by (Niel et al., 1987), "Structural steel erection provides a good example for application of this method. Structural steel normally is estimated and controlled using tons of steel components as the unit of measure. As illustrated in the listing below of subtasks included in steel erection; however, each subtask has a different unit of measure. In such a case, each subtask is weighted according to the estimated level of effort (usually work-hours) that will be dedicated to that subtask. As quantities of work are completed for each subtask, these quantities are converted into equivalent tons and the percent complete calculated as illustrated. The weighting may be changed during the course of a task's completion to reflect quantity or unit rate variances within subtasks. If this is done, it is important that the earned values be recalculated for all subtasks (see the following section for earned value principles)." The following calculation is included in the data listed in Exhibit 4:

Earned Tons to Date = (Quantity Installed to Date) x (Relative Weight) x (520 Tons) / Total Quantity

Percent Complete = 80.5 tons / 520 tons = 15.5%

Wt.	Subtask	U/M	Quan Total	Equiv Steel Ton	Quantity To-date	Earned Tons*
0.02	Run foundation bolts	each	200	10.4	200	10.4
0.02	Shim	%	100	10.4	100	10.4
0.05	Shakeout	%	100	26.0	100	26.0
0.06	Columns	each	84	31.2	74	27.5
0.10	Beams	each	859	52.0	0	0.0
0.11	Cross-braces	each	837	57.2	0	0.0
0.20	Girts & sag rods	bay	38	104.0	0	0.0
0.09	Plumb & align	%	100	46.8	5	2.3
0.30	Connections	each	2977	156.0	74	3.9
0.05	Punchlist	%	100	26.0	0	0.0
1.00	STEEL	TON		520.0		80.5

Exhibit 4 –Weight Equivalent Units (Niel et al., 1990)

After the measuring progress method is determined for each phase code, a field quantity tracking tool must be implemented. Quantity tracking tools may be simple field notes or complex with a sophisticated spreadsheet or purchased construction project controls software. Quantity tracking tools are managed by the field staff and require training and daily effort to keep data current and organized. The importance of proper cost coding cannot be stressed enough. A sample quantity tracking tool is shown in Exhibit 5.

Weekly Field Quantity Report				
Work Completed This Week:				
Cost Code	Description	Unit	Total Completed This Period	Total to Date
302	Concrete Batched	CY	45	500
303	Concrete Placed	CY	42	420
304	Concrete Finished	SF	1200	13400
305	Concrete Forms	SF	1200	13400
306	Concrete Cure	SF	1200	13400

Exhibit 5 - Sample Weekly Field Quality Report

REPORT ANALYSIS

With the field data measured and populated by phase code in a quantity tracking tool, the project team can report the current progress to key stakeholders. The data is prepared in a cost control reporting system that is either manual or computerized. Although labor productivity calculations are straightforward and can be computed on a standard calculator, depending on the size of the project, there may be dozens of cost accounts to track at any given time making hand calculation an expensive task.

Therefore, utilizing a construction management software for cost report is recommended. A variety of software options are available on the market and offer template reports for labor productivity reports. The standard report templates can be edited to conform to company report standards. Tabular reports are commonly used to report data. The standard cost reporting system involves three common reports: daily productivity cost report also referred to as daily cost, weekly labor distribution report (LDR), and monthly cost report.

The daily productivity cost report requires data to be collected daily, which is a labor burden on the project team. The two inputs to the daily cost report are hours and installed quantities. To reduce the labor burden and provide a method to organize labor hours and installed material amounts two tools are utilized. Crew labor hours are input using a daily timecard and required labor hours to be coded correctly to each phase code. The installed quantities are tracked using a daily work report or simple quantities spreadsheet. A sample daily report and sample timecard are shown in Exhibit 6 and Exhibit 7 respectively.

Daily Work Report							
Project: Sample				**Prepared by:**			
Date:				**Comments:**			
Temperature:							
Weather Conditions:							
Phase Code	**Description**	**Labor (h)**	**Supervision (h)**	**Craft-1 (h)**	**Craft-2 (h)**	**Craft-3 (h)**	**Total (h)**
302	Concrete Batched	40	10				50
303	Concrete Placed	50	2				52
304	Concrete Finished	20	4	10			34
305	Concrete Forms	40	4	20	20	20	104
306	Concrete Cure	4	2	2	2	2	12

Exhibit 6 - Sample Daily Work Report

WEEKLY TIME CARD

EMPLOYEE NAME: _____

COMPANY EMPLOYEE IDENIFICATION NUMBER

CLASSIFICATION: _____ **Rate of Pay:** **$65.25**

Day of Week	Date	Phase Code	Regular Hours	Overtime Hours	Notes
Monday	12/3/2018	305	2		Fine tune forms
		302	3	1	Pour day
		303	3	1	
Tuesday	12/4/2018	305	8		Start new forms
Wednesday	12/5/2018	305	8		
Thursday	12/6/2018	303	8	3	
Friday	12/7/2018	304	8	1	
Saturday	12/8/2018				
Sunday	12/9/2018				
Weekly Total:			40	6	

Exhibit 7 – Sample Weekly Time Card

The data from the tracking tools are upload into the cost reporting system, and the daily productivity cost report is distributed to the team for review. The accuracy of the entire cost reporting system depends on the correct application of hours worked to the respective cost accounts (Dozzi, 1993). The report is tabular and communicates budgeted hours, actual hours, planned quantities, install quantities, productivity rate, and daily cost variance. Best practice is for the report to be distributed to the team at the end of each day and discussed with the field crew before starting work the next day, which allows the team to determine if any corrective action is required and plan for changes to the operation.

Weekly labor distribution reports are compiled at the beginning of each week and summarize every phase code that labor and installed quantities were assigned to during the given work period. The LDR combines labor performance and cost. A sample labor distribution report is shown in Exhibit 8. The report is divided into three sections starting from left to right with original estimate values; the second section includes weekly productivity and cost values, and third lists job to date values. The original budget section lists the estimated quantities, unit cost and labor hours. The second section contains the weekly labor productivity performance for cost per unit, labor hours per unit, weekly installed material quantity, and weekly total labor hours for each phase code. The third section provides job to date values for the same metrics listed in the weekly section and also includes the estimated final variance at completion. The report offers a weekly snapshot of the crew's performance and allows for discussion of

implementing corrective actions such as a change in crew size, adding or removing equipment, or changing the crew leader.

WEEKLY LABOR DISTRIBUTION REPORT							
Cost Code	Description	Labor Cost		Quantities		Estimated Cost	
		Week[1]	Cumulative	Week[2]	Cumulative	Per Unit[3]	Total
302	Concrete Batched	3,500	14,000	45	1,200	80.00	160,000
303	Concrete Placed	3,380	13,520	42	1,200	75.00	150,000
304	Concrete Finished	2,380	9,520	1,200	4,800	2.20	13,200
305	Concrete Forms	7,280	29,120	1,200	4,800	5.90	35,400
306	Concrete Cure	780	3,120	1,200	4,800	0.70	4,200
	Total (sum of cost)	17,320	69,280				
1: Labor Cost Week totals are from the Weekly Labor Report 2: Quantities Week totals are from the Weekly Field Quantity Report 3: Estimated Cost Per Unit are shown on project estimate.							

Exhibit 8 – Sample Weekly Labor Distribution Report

The final monthly report should be distributed during month-end reporting and summarizes the project construction progress and the productivity for the given month. Sample monthly reports are shown in Exhibit 9, 10 and 11. The monthly report format is similar to the LDR format with the addition of columns on the far right for forecasted, percent complete and projected total costs. The forecasted cost is calculated in the software using the following equation:

$$\textit{Forecast at Completion (FAC)} = \textit{(ACWP)} + \textit{(BAC} - \textit{BCWP)}$$

FAC = Forecast at Completion

ACWP = Actual Cost of Work Performed

BAC = Budget at Completion

BCWP = Budget Cost of Work Performed

Percent complete is based on the forecast at completion using the following equation; however the percent complete should be based on physical installed material, and the ACWP is replaced by actual units installed.

$$\textit{Percent Complete (Cost)} = \textit{ACWP} / \textit{FAC}$$

Or

$$\textit{Percent Complete (Units)} = \textit{Actual Unit Installed to Date} / \textit{FAC (units)}$$

The monthly report provides a broad view of the project performance and includes all phase codes, unlike the daily and weekly reports. The projected value listed on the monthly cost report is a subjective value that is calculated by the project manager based on discussion with the field crew and other subject matter experts. The projected total cost may not match the forecasted values. Although, the projected value should be based on physical performance the project manager may make a judgment decision to adjust the final projected value because this value is used for financial reporting and is input to the accounting Work in Progress (WIP) report.

Labor Performance Report

Cost Code	Description	Quantities			Cost Per Unit			Variance		Total Cost		Estimated % Complete	
		Per.[1]	Cum.[1]	Est.[2]	Per.[1]	Cum.[1]	Est.[2]	Period[3]	Cum.[4]	Forecast[5]	Est.[2]	Quantity[6]	Cost[7]
302	Concrete Batched	45	500	2000	$77.78	$28.00	$80.00	$ (100)	$(26,000)	$56,000	$160,000	25%	9%
303	Concrete Placed	42	420	2000	$80.48	$33.33	$75.00	$ 230	$(17,500)	$66,667	$150,000	21%	9%
304	Concrete Finished	1200	4800	6000	$ 1.98	$ 1.98	$ 2.20	$ (260)	$ (1,040)	$11,900	$ 13,200	80%	72%
305	Concrete Forms	1200	4800	6000	$ 6.07	$ 6.07	$ 5.90	$ 200	$ 800	$36,400	$ 35,400	80%	82%
306	Concrete Cure	1200	4800	6000	$ 0.65	$ 0.16	$ 0.70	$ (60)	$ (2,580)	$ 975	$ 4,200	80%	19%

Notes:

1 From Labor Distribution Report (LDR)

2 From estimate

3 Formula: Period Variance = (Cost Per Unit Period - Cost Per Unit Estimate) x Quantities Period

4 Formula: Cumulative Variance = (Cost Per Unit Cumulative - Cost Per Unit Estimate) x Quantities Cumulative

5 Formula: Total Cost Forecast = Cost Per Unit Cumulative x Quantities Estimate)

6 Formula: Estimated % Complete = Quantities Cumulative / Quantities Estimate

7 Formula: Estimated % Complete Cost = (Cost Per Unit Cumulative x Quantities Cumulative) / (Cost Per Unit Estimate x Quantities Estimate)

Exhibit 9 - Sample Labor Cost Report with Calculations

MONTHLY COST SUMMARY

		Actuals			To Complete		Forecast Cost	Estimated			Variance	Index
Cost Code	Description	Actual Quantity to Date (AQ)	Actual Cost to Date (AC)	Unit Cost to date (AUC)	Quantity to Complete (CQ)	Cost to Complete (CC)	(FC)	Quantity (EQ)	Unit Cost (EUC)	Total (EC)		
				AC/AQ	(CQ)	(CC)	AC + CC				EC - FC	EC / FC
302	Concrete Batched	500	14,000	28.000	1,500	42,000	56,000	2,000	$80.00	$160,000	104,000	2.86
303	Concrete Placed	420	13,520	32.190	1,580	53,147	66,667	2,000	$75.00	$150,000	83,333	2.25
304	Concrete Finished	4,800	9,520	1.983	1,200	2,380	11,900	4,800	$ 2.20	$ 13,200	1,300	1.11
305	Concrete Forms	4,800	29,120	6.067	1,200	7,280	36,400	4,800	$ 5.90	$ 35,400	(1,000)	0.97
306	Concrete Cure	4,800	3,120	0.650	1,200	780	3,900	4,800	$ 0.70	$ 4,200	300	1.08

Exhibit 10 - Sample Monthly Cost Summary Report

JRRS CONSTRUCTION COMPANY

PERIODIC LABOR COST REPORT

PROJECT 2021:

REPORT DATE: MM-DD-YY

REPORT TYPE: LABOR OPERATIONS REPORT

DATA DATE THROUGH: MM-DD-YY

COST CODE	ACTIVITY DESCRIPTION	LABOR BUDGET	LABOR COST THIS PERIOD	LABOR COST TO DATE	% COMPLETE	PERCENT COMPLETE TIMES BUDGET	VARIANCE UNDER BUDGET (-)	VARIANCE OVER BUDGET (+)	PROJECTED COST TO COMPLETE
1010	Project Supervisor	70000	7000	21000	30	7000	0	0	70000
1050	Field Engineer: Layout, Line & Grade	12000	1100	3900	40	3000	-900		9750
2200	Install & Maintain Silt Fence	3000	300	3240	90	2700		+540	3600
2210	Fine Grade Beneath Spread Footings	4000	490	3100	100	4000	-900		3100
3140	Wall Forming	12190	1230	8120	70	8533	-413		11560
3180	Deck Forming, Pan Slabs	26850	1920	17240	60	16110	-510		28733
3175	Edge Forming, Pan Slabs	36280	2800	13190	40	14512	-1322		32975
3250	Keyway & Waterstop	3100	350	2920	100	3100	-180		2920
3255	Bulkheads & Blockouts	2800	280	940	20	560		+380	4700
3315	Place & Finish Concrete Flatwork	28900	1260	5520	20	5780	-260		27,600
3332	Rub Finish Architectural Concrete	14300	3000	4950	30	4290		+660	16,500
3370	Cure & Protect Concrete	6850	900	3210	40	2740		+470	8025
3215	Install Spread Footing Reinforcing & Chairs & Bolsters	16300	0	15280	100	16300	-1020		15,280
5420	Steel Stud Partition Framing	48105	3800	11210	20	9621		+1589	56050
12350	Install Base Cabinets	13235	0	0	0	0	NA	NA	NA
1560	Job Cleanup	9980	700	2670	30	2994	-324		8900
	ETC. TO BOTTOM LINE TOTALS IN EACH COLUMN	**TOTAL**	**TOTAL**	**TOTAL**	**TOTAL**	**TOTAL**	**TOTAL VARIANCE SHOWN UNDER BUDGET**	**TOTAL VARIANCE SHOWN OVER BUDGET**	**PROJECTED COST TO COMPLETE, LINEAR PROGRESSION ON CURRENT TREND**

Exhibit 11 - Sample Labor Cost Report (Rounds et al., 2011)

To assist with commutating labor productivity, a graphical representation of the data is recommended. A graphical report allows the project team to view trends based on performance curves.

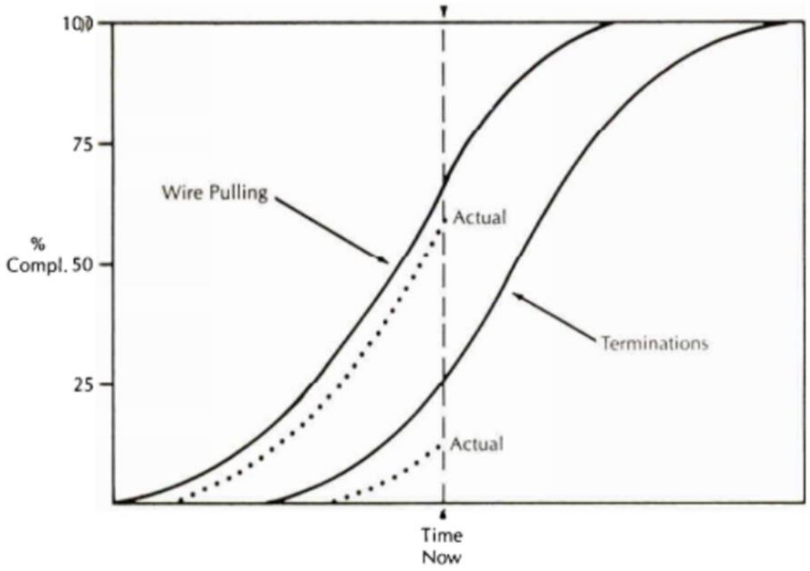

Exhibit 9 - Sample Actual vs. Estimate Trend Graph (Niel et al., 1990)

As shown in the above graph in Exhibit 12 the estimated wire pulling and terminations are shown with the solid black curve based on percent complete and installation time. The actual values that are input to the labor productivity reporting systems are shown as the dotted actual curves. In this example, both the wire pulling and termination phase codes are performing slower than estimated. Also, trend charts can be used to compare the productivity rate as the percent complete increase to provide a reference for the performance at completion compared to the estimated unit rate as shown in Exhibit 13.

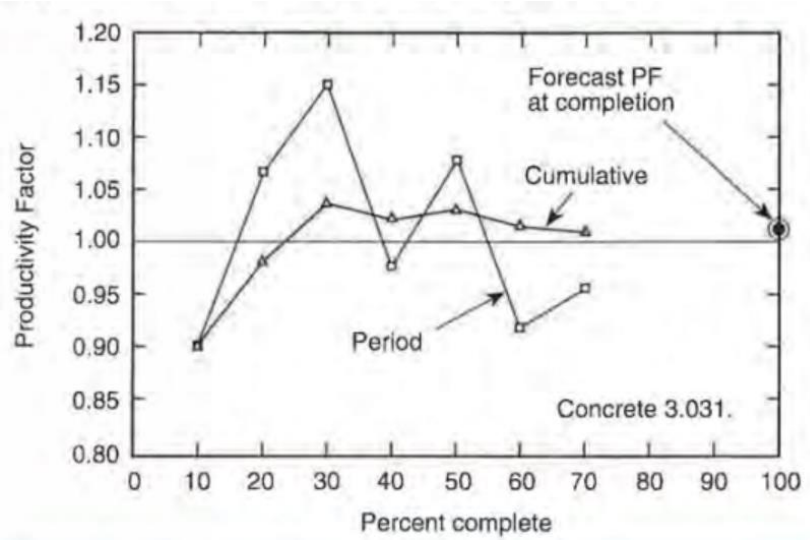

Exhibit 103 - Sample Trend Chart (Dozzi et al., 1993)

BENCHMARKING

Benchmarking is the final part of the labor cost reporting process. At this stage, the completed phase code unit rates saved into the company historical database. This process is referred to as internal field benchmarking and should not be confused with industry or competitor benchmarking. “Internal benchmarking is important to the firm’s continuous-improvement program” (Rojas, 2008). The level of management requires upper management support and should be part of the company management culture to promote continuous improvement productivity improvement. “Upper management must also take the lead in working with workers to ensure that everyone understands the purpose of field benchmarking and how it will be implemented in the field. Without the support of the crew, field benchmarking cannot be effectively implemented” (Rojas, 2008). Buy-in from the project manager, foreman and crew are crucial for the accuracy of labor productivity rates which will establish the company benchmark rates that will be used for future bids and proposals. “Field benchmarking is not about evaluating crew or individual work performance. Field benchmarking is about evaluating and improving the work processes that the crew works within.” (Rojas, 2008).

The benchmark productivity rates also create a competitive environment where crews strive to beat benchmark unit rates and continuously improve. The quantity tracking tool or a benchmark track tool as shown in Exhibit 14, is used on a daily basis to track data to be input to the benchmark trend graph. The graph shown in Exhibit 15, represents a benchmark unit rate with a trend for daily and average

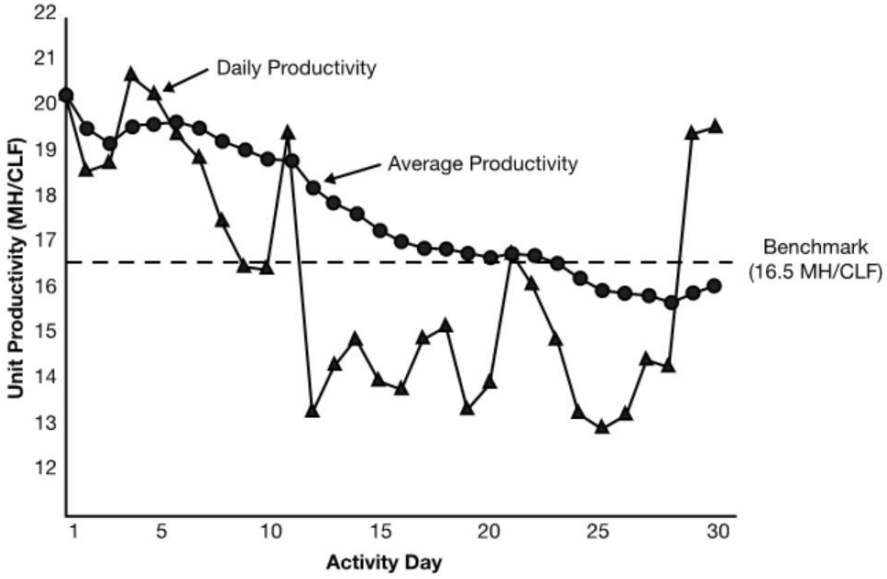

Exhibit 14 – Benchmark Trend Chart (Rounds et al., 2008)

productivity. From day one to day ten productivity exceeded the benchmark rate and peaked on day four at nearly twenty-one MH/CFL, also between day eleven and day twenty-eight productivity was below the benchmark rate.

Activity Description:	6-inch Cable Tray Installation					
Activity Scope	Install 3,000 Linear feet of 6-inch ladder cable tray including supports, fittings, material hangling, and layouts					
Estimated Rate	18.0 MH/CLF					
Activity Benchmark:	16.5 MH/CLF					
	EFFORT		INSTALLED QUANTITY		UNIT PRODUCTIVITY	
ACTIVITY DAY	DAILY (MH)	TOTAL (MH)	DAILY (LF)	TOTAL (LF)	DAILY (MH/CLF)	AVERAGE
1	24	24	118	118	20.3	20.3
2	20	44	108	226	18.5	19.5
3	24	68	129	355	18.6	19.2
4	20	88	97	452	20.6	19.5
5	16	104	79	531	20.3	19.6
6	12	116	62	593	19.4	19.6
7	12	128	64	657	18.8	19.5
8	12	140	69	726	17.4	19.3
9	12	152	73	799	16.4	19.0
10	12	164	73	872	16.4	18.8
11	12	176	62	934	19.4	18.8
12	16	192	120	1,054	13.3	18.2
13	16	208	113	1,167	14.2	17.8
14	16	224	108	1,275	14.8	17.6
15	16	240	115	1,390	13.9	17.3
16	16	256	117	1,507	13.7	17.0
17	8	264	54	1,561	14.8	16.9
18	8	272	53	1,614	15.1	16.9
19	8	280	60	1,674	13.3	16.7
20	8	288	58	1,732	13.8	16.6
21	8	296	48	1,780	16.7	16.6
22	16	312	100	1,880	16.0	16.6
23	24	336	162	2,042	14.8	16.5
24	24	360	180	2,222	13.3	16.2
25	24	384	186	2,408	12.9	15.9
26	16	400	122	2,530	13.1	15.8
27	16	416	111	2,641	14.4	15.8
28	16	432	112	2,753	14.3	15.7
29	24	456	124	2,877	19.4	15.8
30	24	480	123	3,000	19.5	16.0

Exhibit 115 - Benchmark Tracking Table (Rojas et al., 2008)

MODEL PROJECT

DESCRIPTION

The model project prototyping utilizes the applications of cost control and productivity reporting found in the literature research portion of this report in an operating construction project. The construction type selected for the model project is modular construction, which is a combination of assembly line management and traditional vertical construction management. Modular construction is dependent on productivity to move modular units on the assembly line in the most efficient manner possible. Three modular construction projects were selected to participate as model projects and use the cost reporting tools and procedures. The company did not have an existing labor productivity report before the model project implementation as previously mentioned. Team members were provided training during on the job training sessions held during weekly labor cost report meetings. During the meetings, model project participants suggested and implemented changes to the reporting process in real time and continuously improved the reporting process throughout all three projects. The report structure was constrained by the construction management software that the company currently used. The software contained several template reports that were edited to adhere to company standards. Three reports were developed: Labor Production Report, Summary Cost Report and Unit Cost Report.

Existing Reporting Procedures

Existing company reporting procedures and organization process assets were assessed to determine opportunities for cost reporting process improvements. When evaluating construction management software numerous improvement opportunities were discovered. The software is to provide streamlined processes for construction project management; however, a disconnect between the estimate and control budget coding structures due to an issue with the software converting estimated units of measure to lump sum. Lump sum unit of measure is not recommended for self-perform labor because the field crew cannot compare track installed quantities. As previously discussed, each labor phase code should have a specific unit of measure such as square feet or cubic yards. Existing control budget process consists of exporting the estimate data from the estimating software into an excel spreadsheet and editing the coding structure before importing to the cost report system. This process is time-consuming and regularly not complete before starting field operations. Another improvement opportunity involves project teams using a variety of daily reports and timecards templates to track field construction which created problems for tracking completed work. No existing organization process assets were found for cost reporting and quantity measuring with the expectation of the previously mentioned monthly cost projection report. Lastly, although an existing unit cost and productivity rate database was utilized by the

cost estimate team, benchmarking procedures were not defined for benchmarking unit rates during execution, and there is no formal process for updating the database post project closing. Based on the assessment several organizational process assets were develop including: standard phase codes, estimate to control budget process, daily progress reports, craft timecards, quantity tracking tool, productivity reports and benchmarking process.

COST REPORT TOOLS

Before implementing the model project prototypes, labor cost reporting tools were developed based on the improvement opportunities found during the existing reporting procedures assessment. To improve the estimate to control budget conversion the estimating department and operations staff developed a standard phase code system and agreed to common units of measure which were issued into a standard coding structure. A list of the updated phase code is contained in Appendix B. Daily reports and craft timecards templates were standardized and distributed to the project teams to assist with tracking labor hours and installed materials. The updated timecard and daily report templates are contained in Appendix C. Installed material quantity tracking was identified as a process that required improvement; therefore, a tool within the construction management software named Progress Worksheet by Item/Phase was selected to assist with tracking installed materials and is shown in exhibit 16.

Progress Worksheet by Item/Phase

SAMPLE PROJECT

Phase	Description	UM	-------- Current Unit Status -------- Curr Est	Actual	% Comp	Newly Complete	Total Complete
07-4600-	Siding	SF	5,448.00	0.00	0.0		
08-1100-	Hollow Metal Doors & Frames	EA	25.00	0.00	0.0		
08-5000-	Windows	EA	16.00	0.00	0.0		
09-2903-	Gypsum Wallboard VCG	SF	7,680.00	5,398.00	70.3		
09-5100-	Acoustical Ceilings	SF	7,354.00	0.00	0.0		
09-6802-	Walk-Off Mat	SF	125.00	0.00	0.0		
09-6803-	Vinyl Sheet Goods	SF	196.00	0.00	0.0		
09-6804-	Vinyl Flooring	SF	5,090.00	300.00	5.9		
09-7200-	Fiberglass Reinforced Paneling	SF	12,512.00	8,970.00	60.0		

Exhibit 12 Quantity Tracking Tool

The Progress Worksheet lists each phase code and description with a corresponding unit of measure. A field supervisor uses this tool each day along with the proper progress measuring technique for the specific operation. The field supervisor sends the Progress Worksheet to the project engineer to be uploaded to the cost report software at the end of each work day. Productivity rate comparison is made using the Labor Production Report. A sample Labor Production Report is contained in appendix D The report includes all phase codes with the correct unit of measure and columns are populated with databased on estimate units, job to date units and weekly production rates. Unit cost and cost per labor hour comparison are made using the Job Cost Summary Report. A sample Job Cost Summary Report is contained in appendix E. This report includes estimated, actual, projected and forecasted cost data for each phase code. Unit cost including all cost types (labor, materials, equipment) for each phase code at tabulated in the Unit Cost Report. A sample Unit Cost Report is contained in appendix F. The inputs are the labor hours that are uploaded from the timecards and the installed quantities from the Progress Worksheet. The reports are limited to weekly reporting based on the software constraints. The cost reports tools that were used during the model project are contained in Appendix G.

Results

At the conclusion of the three model projects, it was determined that the cost reporting process provided added value for continued improvement and optimizing construction operations based on objective data. Several successes were observed including approval of establishing labor cost reporting standard operating procedures, standardized phase codes with proper units of measure, on the job training, cost report meetings, shorter period to create control budgets, implementation of cost reporting tools, and ability to benchmark unit rates. However, it was clear that there are resistance and hesitation of the project team to use reporting data as a basis of implementing corrective action due to the issue with the timing of actual data being progressed in the software. The data for labor hours is updated weekly on Thursdays one week after the work is complete; therefore, reports are not accurate until a week and a half after the work is complete; which is not a recommended process. If information were distributed in timely report data would provide the team a better opportunity to improve the construction modular construction operations.

For this reason, the project teams chose to use the Cost Summary Report during project review meetings and neglected to use the Labor Production Report and Unit Cost Report. Due to additional software limitations, the use of graphical reporting is not available which limited the project team's ability to make decisions based on data trends. The results before and after implementation of the model project prototypes are listed in Exhibit 17.

Before Model Project Implementation				
Process	***Upper Management***	***Estimators***	***Project Team***	***Field Supervisors***
Cost Control	Monthly Status Report	None	Monthly Projections	None
Estimating	Overhead and Administrative, Select project pursuits	Lead estimates for means and methods	Quantity take-off	Subject matter expert opinions
Corrective Actions	None	None	Monthly basis decisions	None
Control Budget	Approve coding structure	Convert estimate to budget in standard codes	Code hours to standard codes	Timecards to code hours
After Model Project Implementation				
Process	***Upper Management***	***Estimators***	***Project Team***	***Field Supervisors***
Cost Control	Monthly Status Report	None.	Monthly Projections	None.
Estimating	Overhead and Administrative, Select project pursuits, use of standard unit of measure	Lead estimates for means and methods. Use of a standard unit of measure and establish a database.	Quantity take-off.	Subject matter expert opinions
Corrective Actions	Monthly.	None.	Weekly cost report meetings.	Weekly Cost report meetings.
Control Budget	Revision and approval of standard coding structure.	Convert estimate to budget in standard codes. Add revised codes to estimating software.	Code hours to standard codes. Upload actual quantities to reporting software.	Timecards to code hours. Track installed quantities.
Database Benchmarking	None.	Database created.	Comparison of past projects.	None.
Actual Cost and Quantity Tracking	None.	None.	Weekly input and reports.	Tracks hours and installed materials.
Graphical Analysis	None.	None.	None.	None.

Exhibit 13 – Model Project Results Table

Lastly, standard operation procedures and a cost report organizational process were developed. The process is similar to the flowchart shown in exhibit 1; however, the chart provides the information for five processes including the estimate, control budget, weekly reports, monthly reports, and benchmarking;

with process details listed for four sections. The Team section notes the expected roles during each process. Next, called Inputs, includes each specific input that the team will use to complete the process. The third second includes tools for each process and provides the actual report name for each process. Lastly, the Outputs section provides the team with an expected outcome of each cost report process. The cost report process table is contained in appendix H.

MODEL PROJECT TEAM MEMBER SURVEY

SURVEY SUMMARY

A model project survey was issued to the team members who partook in the model project prototyping. The intent of the survey was to gauge the effectiveness of the implemented cost control improvement process and tools used for the model project. A digital survey was sent to the participants and a week response time was allowed. One follow up survey notification was sent to the invited participants. Each survey question allows for the respondent to provide an "Other" response to assist with further improving the cost control process.

EXPECTED OUTCOMES

The expected survey outcomes are as follows:

1. Question 1: Respondents are direct manager of craft employers and self-perform scopes of work.
2. Question 4 and 5: A high percent of respondents will be aware of and trained in the cost reporting system.
3. Question 6: Training will be categorized as Somewhat Useful by a majority of respondents.
4. Question 8: Quantities are tracked on a daily basis.
5. Question 10: A high percentage of respondents will have used the reports.
6. Question 15: Respondents will not respond to have received assistance with labor reports promptly.
7. Question 17: Respondents will provide feedback.

SURVEY AND RESPONSES OF SIGNIFICANCE

The expected outcomes were not realized for outcomes three, four and six. One respondent felt that training was beneficial and two respondents did not receive training and provided additional feedback in the other section of survey three question. Also, for outcome four regarding question eight zero response were received for daily quantity tracking, which is alarming because the labor unit rate tracking requires close attention of completed work. See survey responses for question eight in Exhibit 18. Outcome six surprisingly responded both yes and no for question fifteen.

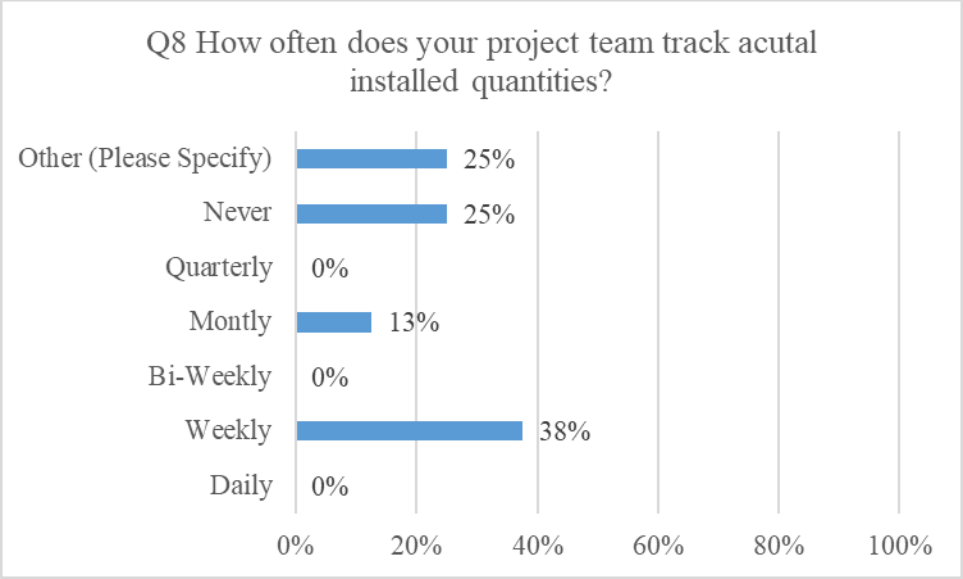

Exhibit 14 - Survey Question 8

Question nine responses were significant because it clearly shows that the team reported that is it difficult to track installed quantities with the existing system. One respondent left feedback for question nine, "The team use the estimated quantities and not actual quantities. I guess the team did not want to put additional efforts required." This response shows there is a lack of understanding on how to track installed materials and report the actual values. See question nine response in Exhibit 19 below.

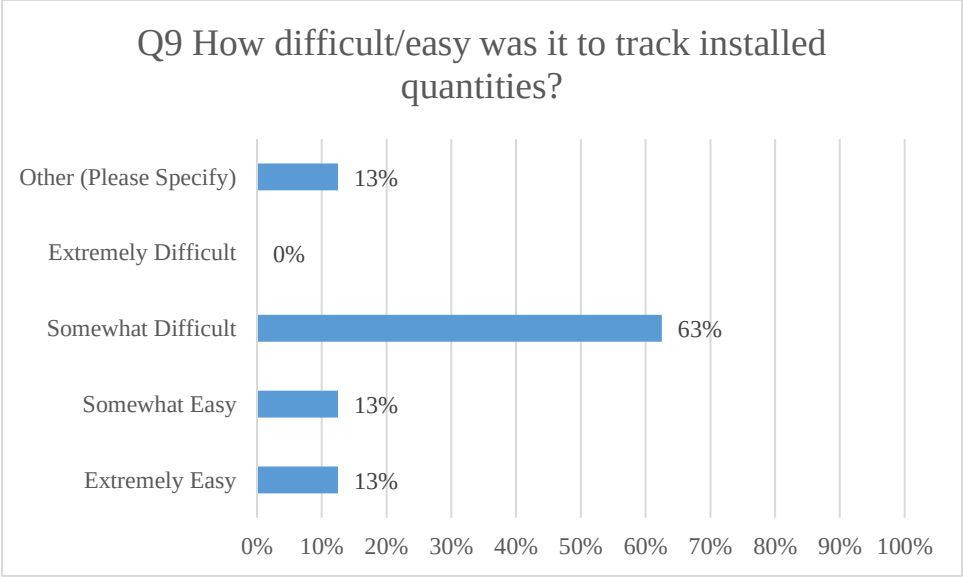

Exhibit 159 - Survey Question 9

Lastly, the team provided significantly more feedback in question seventeen than expected. The general response of reach respondent is that there is a lack of management commitment to the labor cost reporting process, limited standard procedures and lack of training. See question seventeen response in Exhibit 20 below.

Question 17 – Provide feedback/suggestions/comments for the labor cost report process.	
Number	**Response**
1	To provide an opinion about the current labor cost report process, I would like to know what the expectation of the company's leadership is when it comes to project controls? Other than monthly projections, what tools are project teams expected to use and at what intervals to track actual vs. estimate, ETC and EAC, productivity, etc.?
2	There was some difficulty in pulling labor units regarding of familiarity with the various report options, payroll dates (weekly vs. bi-weekly), and access rights within VP. Suggest project teams receive a list of "standard' reports to utilize within the system and a guide on how to enter in the required data to generate those reports in VP.
3	Expectations on how units are progressed and by whom. Our jobs had the Ops Manager progressing the weekly units rather than the individual supervisor or production manager - there may be an opportunity here for streamlining "actual" data collection
4	Weekly report development. Labor posts every Thursday for the previous week. The weekly report was expected to be created and distributed every Friday for a cost report review meeting to be held the following Monday. There was some delay in receiving the unit progress data which delayed the report distribution until later in the week. Depending on the job, a modular project could only last week's vs. months; it is important to receive data timely so that any mitigation efforts and be executed.
5	Weekly report review. The inconsistent cost report review meeting held. Suggest combining this review with the internal project meeting as it would be a more efficient use of time and more team members available should questions arise or actions needed.
6	Final cost report review. We have completed (2) jobs using the weekly job cost summary report. Suggest have a final review will all applicable team members to discuss estimate vs. actual on each job and how that data could be useful in future jobs. Also would be an opportunity to review lesson learned with the reporting process.

Exhibit 16 - Survey Question 17

SUBJECT MATTER EXPERT INTERVIEWS

Three subject matter experts (SME) were interviewed in person regarding the company cost control process. The subject matter experts were selected because of the years of total experience in the construction industry and positive attitude regarding project controls. The goal of the interview questions was to gain an understanding of project management maturity of the company and gauge the company culture regarding labor productivity continuous improvement. The interview also served as a form of

stakeholder engagement to gain buy-in for the new reporting tools. The entirety of the interview responses are contained in Appendix I. SME interview questions are as shown in exhibit 21 below.

Subject Matter Expert Interview Questions	
Number	**Question**
1	Describe a project that you were involved in that used labor reporting. Provide the pros and cons of utilizing labor reporting for this project.
2	Describe the process of gathering data that is required for labor reports. Such as installed quantities, labor hours and rework.
3	Were you provided training for past projects using labor reporting, if so, describe the training process? Also, how were changes to the process implemented?
4	Describe the process of distributing labor reports to project team members. Provide specific examples of successful reports where team members can make corrective actions and track lessons learned.
5	Do you believe that labor reporting brings added value to projects? Describe a specific situation.

Exhibit 17 - SME Interview Questions

An important takeaway from question one responses is the SME are experienced in labor productivity reporting and have experience working for former employers using a similar process. The senior project manager SME surprisingly responded having no experience using a labor cost reporting; however, with further questioning, it was found that the SME had used a similar system and was resistive to implementing a similar process due to lack of time and staff to achieve proper reporting. The senior project manager's response is a follows, "None in my career. No labor hour tracking. Mostly based on projects with minor self-perform work it was hardly worth tracking."

Question two, regarding the process to track quantities, the SMEs all had project experience in the data gathering processes; however, each SME felt that it is less difficult if the system is set up correctly and the scope of work percent complete can be easily measured. The executive SME responded to question two, "After the cost report is set up, time cards are coded to the work activities and the installed quantities for those work activities."

Question three, regarding training, the SMEs shared mixed opinion due to the lack of training. The project manager responded, "Yes, definitely got trained, but training might not be the right word for it, it was more or less on the job training, (I) started off as a field engineer working on time cards and gathering quantities, verifying the supervisor tracking accurately. Input into software, review weekly with project teams in a meeting, code by code and line by line to see mistaken in tracking quantities, project manager can see thing that are going wrong." There is an obvious inconsistency in what is considered training among the SMEs.

For question four, the SMEs had a difference of opinion on how often the reports should be distributed and the overall process of using reports. The contrast of support for applying labor reports is seen between the response of the senior project manager and the project manager; senior project manager response, “How would I best want to see it presented? To be honest, I don’t see much value in getting this on a weekly basis, I haven’t had a recent project that had an operation that is several weeks, but I can see value in large operations like concrete or framing, and my division doesn’t have large enough projects for this tracking.”, project manager response, “Real important to have access to all of the labor reports, need to be run weekly, so you can see how you got there, and notes are important, list assumptions or percent hold back, and have claiming plans to understand percent complete. Import to have that so everyone understands. First digital copy sent out the day before; people will put notes or review by computer. In meetings have paper copies to add notes and things they need to change and quantities that need to be adjusted. Have a copy to implement changes if necessary.”

Question five address the SMEs opinion for the added value of implementing labor cost reporting. All of the SMEs believe there is added value and also expressed several reasons why this is a complicated process to implement into an existing organization. The project manager responded, “Labor reporting is definitely valuable mostly from a financial aspect, it allows you to look at areas you are struggling, and you can focus your time and research to the areas you need to perform the work differently, talk to the supervisor, and get new equipment or tools. Getting the team involved to perform a method analysis for struggling codes. Allows early on that you are struggling, and you don’t get hit on the head and six months in you are losing on a cost code, but it is too late to recover. An additional question was asked: *No standard reporting, do you believe the company should have a system or is this project by project?* Response: Needs to be companywide with a standard report, if you don’t you will have superintendents coming off other projects and not understand the cost reporting strategy, there will be resistance, needs to be an expectation that this is a requirement of your job for accurate labor reporting and tracking.”

CONCLUSIONS & RECOMMENDATIONS

CONCLUSION

The labor productivity is the most considerable cost concern for construction organizations; therefore it is vital that a well-developed reporting system is implemented. Financial accounting procedures alone are not enough to report labor productivity at the project level. The success of construction projects largely depends on the team’s ability to react to cost and schedule variances. A

proper cost reporting system must be implemented to provide advanced level accountability for achieving expected project and organization outcomes.

Research literature advocates for implementing cost control management systems for labor productivity is the main factor that contributes to improved productivity performance. Also, research provided insights to the importance of establishing detailed cost estimates that include standard cost account numbering and descriptions for self-perform work and utilize a historical database for productivity unit rates based on the organization's previous performance. The estimate is vital for establishing a project control budget that is used as the cost control baseline for labor productivity reporting. Progress is measured based on several methods to determine the number of installed materials or percent completed based on the complexity of the scope of work. Using the correct inputs for project reporting is critical to the success reporting process. After the progress is understood and installed quantities are determined, tabular labor cost reports can be developed using construction management software. The report should be distributed timely and reviewed with the project team to take necessary corrective actions. Labor cost reports should be accompanied by a graphical representation of the labor data to evaluate trends and to point out possible outliers in the collected data. Benchmarking the final productivity unit rates for use in future projects is essential in building a company culture for continuous improvement and requires upper management support.

RECOMMENDATION

It is recommended that the construction organization involved with the model project prototyping continue to implement labor cost reporting improvements. The issue with the delayed posting of actual hours and cost into the construction management software is detrimental to the labor cost reporting process; therefore immediate attention is recommended for improving this delay. When the information within the productivity reports is timely and reliable, the project team will buy-into the reports, and all three reports will be utilized. Additionally, graphical reports are not available for the current construction management software. It is recommended that new project controls software is purchased which includes full functionality for the reports provided for this report. A simple Microsoft Excel graph charting tool may be a cost-effective solution if the cost of new software is of concern. It is recommended that weekly meetings to review reports should continue to take place, and include upper management as time allows. One improvement to consider for project cost report meetings is to add a lessons learned section to meeting minutes to capture potential improvement for other teams.

Although the organization has an organized financial management system, several of the model project participants expressed the lack of cost information to support decision making related to production

improvement. Company employees are dissatisfied with their current project controls system which does not provide timely data that could be used to improve current performance. Both the survey and interview responses discussed the need for further training on using reports. It recommended that a formal training session is provided to projects teams before project startup. The project manager and upper management should be present during the training to emphasize accurate reporting. Also, it is recommended that the following message is communicated to project teams, "We must remember, and must reassure the workers, that the intent is not to place blame, but rather to identify where inefficiency lies so that the inefficiency can be eliminated" (Rounds et al., 2011). The survey responses show that employees are hesitant to implement a labor cost reporting system because they would be punished for poor operational productivity. Attention should be placed directly at developing a culture where the work environment displays a strong feeling of comfort when discussing productivity issues. Thus, an improved effort for upper management to provide top-down accountability for building a culture where cost control is a condition of employment at all levels. Access to the project controls system should not be limited to the project manager. To increase accountability for adequately planning, tracking and reporting productivity, the cost controls system should allow access to all team members. Lastly, it is recommended that a project control manager position is added to the corporate structure. Although this may not be a popular suggestion due to the added overhead cost to the organization, the need for a person to champion the effort of structured cost control and reporting is necessary.

CONTRIBUTION TO THE PROJECT MANAGEMENT BODY OF KNOWLEDGE

This report includes the use of several PMBOK knowledge areas with Cost Management being the key knowledge area for contributing to the PM Body of Knowledge. While PMI offers the Construction Extension to the PMBOK Guide, this document is lacking the specific detail for cost reporting for self-perform labor productivity. This project furthers the linkage between the PMBOK and the construction industry by displaying the use of the tools and techniques as described in section seven of the Construction Extension to the PMBOK Guide. Exhibit 22 includes expected and actual outcomes for improving section seven.

Section 7 Project Cost Management	Expected Outcomes	Actual Outcome
7.2.1.2 Parametric Estimating	Use of parametric estimate to develop control budget and use of cost reporting to establish historical data for future cost estimates, also to expand the details shown in Table 7-2.	Add flowchart in Exhibit 1 to this section. Add detail for historical database estimating.
7.2.7 Determine Budget	Establish control budget for labor costs and use cost baseline with unique coding structure to communicate with project members.	Recommendation for the use of CIS MasterFormat. The model project provides a sample coding list.
7.3.1 Actual Cost	Establish a process for collection and reporting of weekly labor cost and installed materials.	Add sample quantity and labor tools such as Exhibit 4 and Appendix D.
7.3.3 Progress and Performance Reviews	Create reports to communicate weekly labor cost and installed materials to implement corrective action.	Three reports: Labor Production Report, Summary Cost Report and Unit Cost Report.

Exhibit 18 - PMBOK Construction Extension Improvements

AREAS FOR FURTHER RESEARCH

- Risk-based productivity report which includes the forecasted unit rate based on known risk factors.
- Contingency-based productivity reporting
- Research graphical analysis tools
- Compare construction management software for cost reporting features
- Estimate historical database setup and management
- Cost analysis of implementing cost reporting system within a company

REFERENCES

A guide to the project management body of knowledge (PMBOK® Guide). (2017). Newtown Square, PA: Project Management Institute.

Bourne, L. (2016). Stakeholder Relationship Management: A Maturity Model for Organisational Implementation. London: Taylor and Francis.

Construction Extension to the PMBOK (4th ed.). (2016). PMI.

CSI MasterFormat 2010 Sample Cost Codes. (2011, May 9). Retrieved September 5, 2018, from

Dozzi, S., & AbouRizk, S. (1993). Productivity in Construction. National Research Council Canada NRCC-37001

Kern, A. P., & Formoso, C. T. (2016). A model for integrating cost management and production planning. Journal of Financial Management of Property and Construction, 11(2).

Kerzner, H. (2013). Project management metrics, KPIs, and dashboards: A guide to measuring and Monitoring project performance. Hoboken, NJ: John Wiley & Sons.

Kuehn, U. (2011). Integrated Cost and Schedule Control in Project Management. Management Concepts.

Neil, J. (1990). Project Control for Construction. The Construction Industry Institute Cost/Schedule Controls Task Force, 6-5.

Neuendorf, S. (2002). Project measurement. Management Concepts.

Rojas, E. M. (2008). Construction productivity: A practical guide for building and electrical contractors. Boca Raton, FL: J. Ross.

Rounds, J. L., & Segner, R. O. (2011). Construction supervision. Hoboken, NJ: John Wiley & Sons.

Park, H. (2006). Conceptual framework of construction productivity estimation. KSCE Journal of Civil Engineering, 10(5), 311-317. doi:10.1007/bf02830084

Park, H. (2003). Development of a Construction Productivity Metrics System (Doctoral dissertation, University of Texas at Austin, 2002) [Abstract]. (UMI No. 3099511)

Woo, S. K. (1999). “Monte carlo simulation of labor performance during overtime and its impact on project duration.” Dissertation, Department of Civil Engineering, University of Texas, Austin, TX.

SIGNATURE PAGE

APPENDIX

APPENDIX A – MASTERFORMAT CODES

APPENDIX B – COMPANY PHASE CODE LIST

APPENDIX C – TIMECARD AND DAILY REPORT TEMPLATES

APPENDIX D – SAMPLE LABOR PRODUCTION REPORT

APPENDIX E – SAMPLE JOB COST SUMMARY REPORT

APPENDIX F – SAMPLE UNIT COST REPORT

APPENDIX G – MODEL PROJECT REPORTS

APPENDIX H – COST REPROT PROCESS TABLE

APPENDIX I – INTERVIEW AND SURVEY RESPONSES

Interview Question One: Describe a project that you were involved in that used labor reporting. Provide the pros and cons of utilizing labor reporting for this project.
Senior Project Manager: None in my career. No labor hour tracking. Mostly based on projects with minor self-perform work it was hardly worth tracking. ***How do you know if your project is over budget?*** Percent complete and labor hours. More extensive projects would justify closer budget tracking, (maybe) 1000 hour activity.
Project Manager: Every project I have ever worked on has some form of labor reporting, some are more advanced than others. Cons: takes a lot of work, you have to daily timecards, and you have to make sure your foreman are trained on using timecards, and that can take some time. Pros: you can use the labor and codes to estimate a future project, also look for indicators that you may not hit your unit cost which is typically your labor divided by your units you are installing, and you can look at these rates over time to make sure you don't run over the budget.
Executive: All the projects I have been involved with since say 1981 have utilized cost coding of time and the reporting of quantities on a weekly basis. This process was used by at least six construction firms. Provide the advantages and cons of utilizing labor reporting for this project. The pros include a real-time indication of productivity and cost relative to budget, percent complete by activity and a variance to show where the cost will likely end upon completion of the work. These are all very valuable pieces of information to manage the work. The cons, if employees and supervisors do not provide accurate info or are miscoding labor hours of under/over reporting quantities the information is invalid. Also, there are additional administrative costs to manage the system.
Interview Questions Two: Describe the process of gathering data that is required for labor reports. Such as installed quantities, labor hours and rework.
Senior Project Manager: Yes, Washington based contractor had enough volume of work and labor hours for superintendent would track labor hour, didn't really have review but had monthly meetings with self-made forms not a standard software, really complicated excel files, but I will tell you with mechanical work it is hard to track unit rates, difficult to track. Wanted to track each unit but would take an extra person to track it. *How about changing crew size?* For specific tasks, you can estimate based on the combined crew and unit rates. Only for the budget, no tracking in the field, compare percent complete against the budget.
Project Manager: This is typically easy if you set it up right. If you have foreman in the field that is responsible for tracking labor hours and quantity's on a daily basis, have they have a timecard that gives you the ability to code hours and track quantities. Re-work is typically straightforward, set up a new code; some companies designate an R and track to the re-work. Trust but verify, in our business, a carpenter or laborer might not have worked for a company before that reporting this seriously, so you need to review with the foreman on a daily basis until they understand the value.
Executive: After the cost report is set up, time cards are coded to the work activities and the installed quantities for those work activities
Interview Question Three: Were you provided training for past projects using labor reporting, if so, describe the training process. Also, how were changes to the method implemented?
Senior Project Manager: No structured training at the current company. Minimal on-the-job training at past companies.
Project Manager: Yes, definitely got trained, but training might not be the right word for it, it was more or less on the job training, started off as a field engineer working on time cards and gathering quantities, verifying the foreman tracking accurately. Input into soft wear, review weekly with project team in a

meeting, code by code and line by line to see mistaken in tracking quantities, project manager can see thing that are going wrong.
Implementing change?
Depends on the systems, need to understand what it needs to do first and then make changes. As people are higher up the chain may have a way that they want to see it, but you need a program that the right foundation. If the program doesn't track quantities, it makes it more challenging obviously.

Executive: Code and quantiles training was provided down to the Lead level. Also, how were changes to the process implemented? Changes were made in the level of cost tracking observed, the cost items were too small to track.

Interview Question Four: Describe the process of distributing labor reports to project team members. Provide specific examples of successful reports where team members can make corrective actions and track lessons learned.

Senior Project Manager: How would I best want to see it presented? I don't see much value in getting this on a weekly basis, I haven't had a recent project that had an operation that is several weeks, but I can see value in large operations like concrete or framing, my division doesn't have large enough projects for this tracking.

Project Manager: It is essential to have access to all of the labor reports, need to be run weekly, so you can see how you got there, and notes are important, list assumptions or percent hold back, and have claiming plans to understand percent complete. Import to have that so everyone understands.
First digital copy sent out the day before; people will put notes or review by computer. In meetings have paper copy's to add notes and things they need to change and quantities that need to be adjusted? Have a copy to implement changes if necessary.

Executive: Labor report were provided almost two weeks after the week closed which is too long, need to shorten the duration. Provide specific examples of successful reports where team members can make corrective actions and track lessons learned. Still in the implementation and discovery mode at this company.

Interview Question Five: Do you believe that labor reporting brings added value to projects? Describe a specific situation.

Senior Project Manager: With large enough operations yes. What do you do when you get the report? Figure out why with the superintendent. Only so much can be done in the office, so you need to understand at the field level why you are ahead or behind. What are you going to do just fire and hire new people? There might not be a lot of change for the effort of tracking. Other times it doesn't matter. Corrective actions: better equipment, your job to get materials onsite, supervision paying attention, explaining work correctly, re-work factored into productivity.

Project Manager: Labor reporting is definitely valuable mostly from a financial aspect, it allows you to look at areas you are struggling, and you can focus your time and research to the areas you need to perform the work differently, talk to a supervisor, and get new equipment or tools. Getting team involved performing method analysis for over budget cost codes. Allows visibility early on that you are struggling, and you don't get hit on the head and six months in you are losing on a code, but it is too late to recover.

No standard reporting, do you believe the company should have a system or is this project by project?
Needs to be companywide with a standard report, if you don't you will have superintends coming off other projects and not understand the cost reporting strategy, there will be resistance, needs to be an expectation that this is a requirement of your job for accurate labor reporting and tracking.

Executive: Before cost reporting, we had no idea of our productivity or whether our estimated values were consistent with performance.